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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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[Title of Invention] SURFACE ACOUSTIC WAVE DEVICE AND METHOD OF MANUFACTURING A SEMICONDUCTOR DEVICE

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[Title of Invention] SURFACE ACOUSTIC WAVE DEVICE AND METHOD OF MANUFACTURING A SEMICONDUCTOR DEVICE

[Claims for patent]

[Claim 1] A method of manufacturing a surface acoustic wave device, comprising:

a step of applying a resist on a piezoelectric substrate,

a step of forming a resist groove pattern by pressing a template having a desired recess-and-protrusion pattern formed on a surface thereof to the resist on the piezoelectric substrate , and

forming an electrode film pattern based on the resist groove pattern.

[Claim 2] A method of manufacturing a surface acoustic wave device as claimed in claim 1, wherein the step of forming the electrode film pattern comprises a step of depositing an electrode film and a lift-off step of removing a part of the electrode film together with the resist groove pattern.

[Claim 3] A method of manufacturing a surface acoustic wave device as claimed in claim 1, comprising a step of depositing the electrode film prior to the step of applying the resist, the step of forming the electrode film pattern comprising patterning the electrode film.

[Claim 4] A method of manufacturing a surface acoustic wave device as claimed in any one of claims 1 to 3, wherein the template is made of silicon, a silicon dioxide film, silicon glass, sapphire, sapphire glass, polymeric resin, Invar, or Kovar.

[Claim 5] A method of manufacturing a surface acoustic wave device as claimed in any one of claims 1 to 4, wherein the recess-and-protrusion pattern is formed on the template by lithography using electronic beam exposure.

[Claim 6] A method of manufacturing a surface acoustic wave device as claimed in any one of claims 1 to 5, wherein an organic polymer thin film having a hydrophobic group is formed on the surface of the template.

[Claim 7] A method of manufacturing a surface acoustic wave device as claimed in any one of claims 1 to 6, further comprising, following the step of forming the resist groove pattern, a step of ashing the resist groove pattern.

[Claim 8] A method of manufacturing a surface acoustic wave device as claimed in any one of claims 1 to 7, wherein the electrode film pattern has an electrode width smaller than 0.4μm.

[Claim 9] A method of manufacturing a semiconductor device, comprising:

a step of applying a resist on a substrate, and

a step of forming a resist groove pattern by pressing a template having a desired recess-and-protrusion pattern formed on a surface thereof to the resist on the substrate .

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

This invention relates to a method of manufacturing a surface acoustic wave device and a semiconductor device and, in particular, to a method which enables low-cost mass-production of the device highly accurately determined in working frequency and working wavelength even in a high-frequency region or in a short-wavelength region.

[0002]

[Related Art]

A surface acoustic wave device is a device which generates a surface acoustic wave on a surface of a substrate by an interdigital transducer or electrode formed on a piezoelectric substrate, and is widely used in the wireless communication field as a band filter or a resonator. Especially, the device used as a band-pass filter is small in size and has a steep out-of-band removal characteristic as compared with a dielectric filter or a laminated LC filter. Therefore, the surface acoustic wave device is a mainstream band-pass filter for

use in cellular phones and the like. Further, in addition to electric and communication fields, the device has widely been used in a wide variety of fields including the biological chemistry field, for example, in sequencing DNAs.

[0003]

The surface acoustic wave device used in the wireless communication field has the interdigital electrode which generates the surface acoustic wave on the surface of the piezoelectric substrate. The width of the interdigital electrode depends on a wavelength which is determined by a working frequency. For example, in case where the surface acoustic wave device is used as a resonator, the width of the interdigital electrode is set to the value equal to 1/4 of the wavelength which is obtained by dividing an acoustic velocity of the surface acoustic wave by a resonance frequency of the resonator. The recent development in photolithography technology using general light enables, in the wireless communication field, commercial production of the device having an electrode width of 0.4μm which applies to the frequency band of 2.4GHz used in Bluetooth or wireless LAN.

[0004]

As a method of forming a fine electrode pattern on the surface acoustic wave device, a lift-off method is well known. In the lift-off method, at first a resist pattern is formed on the piezoelectric substrate by photolithography using the general light. Next, a metal film is formed throughout the whole surface of the substrate and then an unnecessary portion of the metal film is peeled off together with a resist. Thus a metal electrode pattern is formed. Alternatively, another method of forming an electrode is also known in which, after a metal film for an electrode is formed on the piezoelectric substrate, a resist pattern is formed by photolithography using the general light and then the metal film is etched along the resist pattern.

[0005]

[Problems to be solved by the Invention]

In recent years, following severe shortage of available frequency resources and development of broadband wireless communication, the frequency band of electric waves for use in communication is shifting to a higher frequency band. For example, the frequency band used in the wireless LAN is shifting to a higher frequency band, i.e., from 2.4 GHz to 5GHz and to 26GHz. In addition, it is anticipated that the frequency band used in the 4th generation mobile phone will be 5GHz or a higher frequency band. Accordingly, the surface acoustic wave device is required to have a performance which is appropriate for use in a high frequency region or in a short -wavelength region.

[0006]

As described above, the width of the interdigital electrode is determined by the working frequency. As the working frequency is higher, the width of the electrode becomes narrower. Upon manufacture of the surface acoustic wave device which is used in a high frequency band and which has a narrow electrode width, it is required to form a high-accuracy resist pattern in order to reduce an error of the electrode width.

[0007]

For example, when the surface acoustic wave device is manufactured by using a $LiTaO_3$ substrate as the piezoelectric substrate, in order to cope with a shorter wavelength of the surface acoustic wave following shifting to a higher frequency, it is necessary to form a high-accuracy resist pattern which can realize the electrode width smaller than 0.4 μm within an error range of 1% or less. It is difficult to manufacture such high-accuracy resist pattern by the conventional photolithography technique using the general light. Even when a substrate made of another material such as a $LiNbO_3$ substrate, a crystal substrate, a diamond thin film substrate or a ZnO thin film substrate is used as a piezoelectric substrate, the electrode width is not different from the above-mentioned electrode width by an order of magnitude although the electrode width may slightly differ due to the difference in acoustic velocity. Thus, the

photolithography technique using the general light reaches an applicable limit.

[0008]

On the other hand, as a technique capable of forming a fine and high-accuracy resist pattern, a lithography technique of irradiating a resist by the use of an electronic beam to expose the resist is known. In this technique, it is possible to realize the electrode width smaller than 0.4μm with an accuracy of one nanometer or less. However, upon forming the resist pattern by electron beam exposure, electron beam writing is performed on the resist along a pattern. Therefore, the above-mentioned technique has a drawback that the throughput is low as compared with the photolithography technique capable of performing one-shot exposure. Moreover, change in outside air temperature leads to thermal expansion and contraction of the substrate, which may cause a writing error due to time-to-time change. Because of the high accuracy, such error is not negligible and, as a result, mass production is difficult.

[0009]

The object of the present invention is to solve the above-described problems in the conventional technique and to provide a method of manufacturing a surface acoustic wave device and a semiconductor device, which enables low-cost mass-production of the device highly accurately determined in working frequency and working wavelength even in a high-frequency region or in a short-wavelength region.

[0010]

[Means to solve the problems]

In order to achieve the above-mentioned object, a method of manufacturing a surface acoustic wave device according to the present invention comprises a step of applying a resist on a piezoelectric substrate, a step of forming a resist groove pattern by pressing a template having a desired recess-and-protrusion pattern formed on a surface thereof to the resist on the piezoelectric substrate, and a step of forming an electrode film pattern based on

the resist groove pattern.

[0011]

According to the present invention, in the step of forming the resist pattern, the resist film is formed into the pattern having desired recesses and protrusions by pressing the template onto the surface of the resist film. Therefore, any exposing step using light or an electron beam is not necessary. Because of such a batch transfer technique simply by pressing the template against the resist, the surface acoustic wave device having an electrode width with high dimensional accuracy can be manufactured with high throughput.

[0012]

A method of manufacturing a semiconductor device according to the present invention comprises a step of applying a resist on a substrate, and a step of forming a resist groove pattern by pressing a template having a desired recess-and-protrusion pattern formed on a surface thereof to the resist on the substrate.

[0013]

By employing the step of patterning the resist by the use of the template, a pattern having a high dimensional accuracy can be formed with high throughput.

[0014]

In the method of manufacturing the surface acoustic wave device according to the present invention, the step of forming the electrode film pattern may comprise a step of depositing an electrode film and a lift-off step of removing a part of the electrode film together with the resist groove pattern. Alternatively, the method may comprise a step of depositing the electrode film prior to the step of applying the resist and the electrode film may be patterned in the step of forming the electrode film pattern.

[0015]

In the method of manufacturing the surface acoustic wave device

according to the present invention, the recess-and-protrusion pattern is preferably formed on the template by lithography using electronic beam exposure.

By using the lithography technique which uses the electronic beam exposure as a method of producing the template, the pattern can be formed with an accuracy of a nanometer order. Moreover, reuse of the template prevents time-to-time change in the electronic beam exposure depending upon the outside air temperature or the like.

[0016]

In the surface acoustic wave device according to the present invention, the template is preferably made of silicon, a silicon dioxide film, silicon glass, sapphire, sapphire glass, polymeric resin, Invar, or Kovar.

As a material of the template, it is desirable to use silicon or a silicon dioxide film which is excellent in fine processability, quartz such as silicon glass, sapphire or sapphire glass which is hard and has a low coefficient of thermal expansion, polymeric resin which can be easily processed, or if a metal material is used, Invar or Kovar, which has a low coefficient of thermal expansion.

[0017]

In the method of manufacturing the surface acoustic wave device, it is preferable to form, on the surface of the template, an organic polymer thin film having a hydrophobic group. In this case, the template can be easily peeled off from the resist.

[0018]

Preferably, the method of forming a surface acoustic wave device according to the present invention further comprises, following the step of forming the resist groove pattern, a step of ashing the resist groove pattern. In this case, by removing the resist remaining in the recesses, it is possible to prevent the metal film for an electrode from being peeled off.

[0019]

In the method of manufacturing a surface acoustic wave device, it is preferable that the electrode width of the electrode film pattern is smaller than 4μm.

The method according to the present invention is effectively used in case of manufacturing the surface acoustic wave device mainly for use with the working frequency equal to or higher than 2.5GHz or mainly for use with the working wavelength shorter than 1.6μm.

[0020]

[Embodiment of the Invention]

Hereinbelow, with reference to the drawing, the present invention will be described in detail in connection with an embodiment of the present invention. Fig. 1 shows a procedure of a method of manufacturing a surface acoustic wave device according to one embodiment of the present invention. Fig. 2 schematically shows a manufacturing process of the method of manufacturing the surface acoustic wave device in Fig. 1 by each manufacturing step. Referring to Fig. 1 and Fig. 2, description will be made about the method of manufacturing the surface acoustic wave device.

[0021]

At first, as shown in Fig. 2(a), a flat resist film 2 is formed on a piezoelectric substrate 1 by a spin-coat method (step S1). As the piezoelectric substrate 1, use may be made of a piezoelectric substrate made of a single crystal such as $LiTiO_3$, $LiNbO_3$ or a crystal, a substrate having an insulating film formed on the above-mentioned substrate, a substrate made of a ceramic piezoelectric material such as PZT or PLZT, or a laminated substrate comprising a substrate and a thin film such as a diamond thin film or a ZnO thin film laminated thereon.

[0022]

Next, as shown in Fig. 2(b), a template 3 having an interdigital electrode pattern 4 formed on its upper surface is pressed onto the substrate 1. In this

manner, as shown in Fig. 2(c), the fine interdigital electrode pattern 4 on the template 3 is transferred onto the resist film 2 to thereby form a desired resist pattern 5 (step S2). It is desired to preliminarily prepare the template 3 by the use of the high-accuracy lithography technique using electrode beam exposure.

[0023]

As a material of the template 3, silicon or a silicon dioxide film on a silicon substrate is preferably used because the fine processing technology therefor is in the highest progress. In this event, the processing is easy. A quartz material such as silicon glass, sapphire, or a sapphire glass which is hard and has a small thermal expansion coefficient is also preferable so as to considerably relieve a temperature control condition during pattern transfer. In case where the temperate made of the above-mentioned material transparent for the visible light, alignment with the substrate becomes easy. Alternatively, as a material of the template, a polymeric resin, which can be easily processed, may be used. Since the temperature control condition during pattern transfer is significantly relived in the above-described method, it is desired to use, in case of a metal material, Invar or Kovar which has a low coefficient of the thermal expansion. Moreover, it is preferable to form an organic polymer thin film having a hydrophobic group on the surface of the template 3 to a thickness such that the pattern accuracy is not affected or to a thickness preliminarily incorporated into the pattern accuracy as the thickness of the thin film. In this case, the template 3 can be easily removed from the resist 2.

[0024]

Next, the resist film 4 in Fig. 2(c) is totally subjected to ashing to remove the resist remaining in the recesses (grooves) of the resist pattern 5 (step S3). By the ashing, as shown in Fig. 2(d), the surface of the piezoelectric substrate 1 is exposed in the recesses of the resist pattern 5. Successively, as shown in Fig. 2(e), a metal film 6 for an electrode is deposited by sputtering (step S4). Thereafter, by a lift-off method of peeling off the resist film 2 together with the

metal film 6 formed thereon, a structure comprising the piezoelectric substrate 1 and a fine electrode pattern 7 formed thereon is obtained, as shown in Fig. 2(f) (step S5). The width of the electrode pattern 7 is equal to 1/4 of the wavelength □ which is calculated from a general working frequency. By minutely measuring and selecting the pattern of the template 3, the accuracy of one nanometer or less can be achieved even for the electrode width smaller than 0.4μm,

[0025]

The surface acoustic wave device thus manufactured is separated into individual chips by dicing and then packaged. Since the pattern can be batch-transferred to the resist film on the substrate, the electrode forming step achieves high throughput and is suitable to mass-production. Thus, the device highly accurately determined in working frequency and working wavelength even in a high frequency region or in a short-wavelength region can be mass-produced at low cost.

[0026]

In the foregoing embodiment, description has been made of the lift-off method by way of example. However, the method of manufacturing the surface acoustic wave device of the present invention is not limited to the above. For example, the electrode film may be deposited prior to the step of applying the resist and, after forming the resist pattern by patterning the resist film, the electrode film may be etched by the use of the resist pattern as a mask.

[0027]

While this invention has thus been described in conjunction with the preferred embodiment thereof, the method of manufacturing the surface acoustic device and the semiconductor device according to the present invention is not limited to the above-described embodiment. The scope of the present invention encompasses various methods of manufacturing the surface acoustic wave device and the semiconductor device in which various modifications and changes are made from the above-described embodiment.

[0028]

[Effect of the Invention]

As described above, in the method of manufacturing the surface acoustic wave device and the semiconductor substrate according to the present invention, the high-accuracy template is preliminarily prepared and the template is pressed onto the resist film applied on the substrate to thereby form the resist film into the resist pattern having the desired recesses and protrusions. Thus, the device highly accurately determined in working frequency or working wavelength even in a high-frequency region or a short-wavelength region can be mass-produced at low cost.

[Brief Description of the Drawing]

[Fig. 1]

A flowchart showing a procedure of a method of manufacturing a surface acoustic wave device according to an embodiment of the present invention.

[Fig. 2]

Schematic views showing a manufacturing process of the method of manufacturing the surface acoustic wave device shown in Fig. 1.

[Description of the Reference Numerals]

1 Piezoelectric substrate

2 Resist film

3 Template

4 Fine interdigital electrode pattern

5 Resist pattern

6 Metal film for an electrode

7 Electrode pattern

[Name of Document] ABSTRACT

[Abstract]

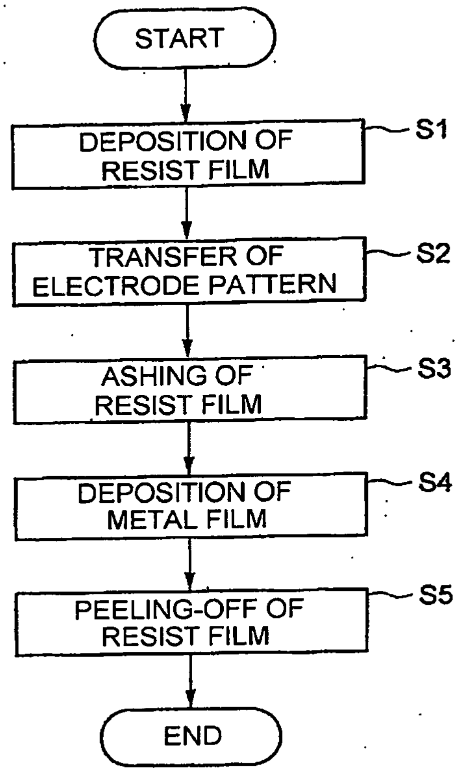
[Object] To provide a method of manufacturing a surface acoustic wave device, which enables the surface acoustic wave device highly accurately determined in working frequency to be mass-produced at low cost.

[Solving Means] A template 3 preliminarily prepared to have high-accuracy recesses and protrusions by a lithography technology employing an electron beam is pressed onto a resist film 2 applied on a substrate to transfer a resist pattern. A thin metal film 6 for an electrode is deposited on the resist pattern 5 which is formed by transfer and is peeled off by a lift-off method together with the resist film 2.

[Selected Figure] Fig. 2.

[Name of Document] DRAWING

[Fig. 1]



[Fig. 2]